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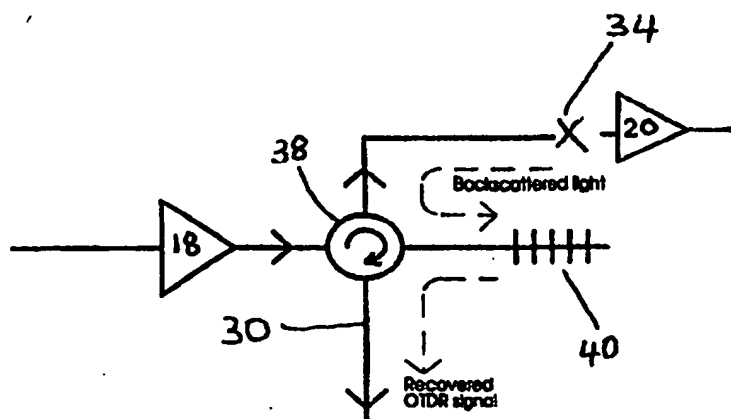
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(54) Title: IMPROVEMENTS IN FIBRE-BREAK DETECTION IN OPTICAL SIGNAL TRANSMISSION NETWORKS



(57) Abstract

A bi-directional optical signal transmission network comprises an outbound (12) and an inbound (14) fibre each including an optical amplifier/repeater (18/24). An optical coupling (30, 38, 40) communicates between one of the fibres (12), to the output side of the amplifier/repeater (18) and the other fibre (14). The coupling includes a filter (40) which is arranged to permit transfer of a test signal wavelength between the outbound (12) and the inbound (14) fibre but which prevents transfer of unwanted traffic signal.

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IMPROVEMENTS IN FIBRE-BREAK DETECTION IN OPTICAL SIGNAL TRANSMISSION NETWORKS

This invention relates to fibre break detection in optical signal transmission networks and more particularly to such networks employing optical amplifiers.

5 Optical fibre break detection is well known in which a signal is sent from one end of the fibre, is reflected from the break back to the sending end and used to determine the break position as a function of the time delay between sending and receiving back the signal. Such a system is known as Optical Time Domain Reflectometry (OTDR). In the case of long haul optical transmission networks it is
10 necessary to employ one or more amplifier/repeater in order to compensate for signal degradation which occurs with increasing distance along the fibre. The amplifier/repeater in such a system are unidirectional and this prevents the use of conventional OTDR launching a probe pulse and detecting the backscattered signal on the same fibre.

15 Long haul amplified/repeated optical transmission systems normally employ pairs of fibres one for outbound signals and one for inbound signals each having unidirectional amplifier/repeaters and various optical coupler arrangements have been proposed which are intended to facilitate OTDR in such systems. Two arrangements known to us are described in:-

20 (1) Novel Coherent Optical Time Domain Reflectometry For Fault Localisation of Optical Amplifier Submarine Cable Systems.

Yukio Horiuchi et al. - KDD Laboratories

IEEE Photonics Technology Letters, Vol.2, No. 4 April 1990.

(2) Fault Location on Optical Amplifier Submarine Systems

Masatoyo Sumida et al. - NTT Transmission Systems Laboratories

IMTC, 10 May 1994, 0-7803-1880-3/94 IEEE

There are disadvantages with these known arrangements and the present
5 invention seeks to provide an improvement over such arrangements.

According to the invention there is provided a bi-directional optical signal
transmission network, comprising an outbound and an inbound fibre each including an
optical amplifier/repeater, optical coupling means communicating between one of the
fibres, to the output side of the amplifier/repeater, and the other fibre and including a
10 filter which is arranged to permit transfer of a test signal wavelength between the
outbound and the inbound fibre but which prevents transfer of a unwanted traffic
signal.

The network may comprise an additional optical coupling means
communicating between said other fibre, to the output side of the amplifier/repeater,
15 and said one of the fibres and including a second filter which is arranged to permit
transfer of a test signal wavelength between the inbound and outbound fibre but which
prevents transfer of a unwanted traffic signal.

The or each coupling means may comprise an optical fibre including a
transmission filter which permits passage of the test signal wavelength but which
20 prevents transfer of the wanted traffic signal, which coupling means is provided at each
end with a tap coupler to a different one of the inbound and outbound fibres.

The or each coupling means may comprise an optical fibre including a
transmission filter which permits passage of the test signal wavelength but which
prevents transfer of the wanted traffic signal, which coupling means comprises one end

with a 3 port circulator having input and output ports for the outbound fibre and an intermediate port coupled with the fibre of the coupling means and at the other end a tap coupler to the inbound fibre.

5 The or each coupling means may comprise an optical fibre including a transmission filter which permits passage of the test signal wavelength but which prevents transfer of the wanted traffic signal, which coupling means comprises at each end a 3 port circulator one for each of the outbound and inbound fibres each circulator having an input and output port for their particular outbound or inbound fibre and another port coupled with the fibre of the coupling means.

10 The or each coupling means may comprise an optical fibre, a four port circulator, a tap coupler and a reflection filter which reflects the test signal wavelength but not traffic signals, the four port circulator having its ports one to four in the circulating direction coupled one to the outbound fibre from the amplifier/repeater, two to the continuation of the outbound fibre three to the reflection filter and four to one
15 end of the optical fibre of the coupling means whilst the tap coupler is coupled via the other end of the optical fibre of the coupling means to the inbound fibre.

The or each coupling means may comprise an optical fibre, a four port circulator, a three port circulator and a reflection filter which reflects the test signal wavelength but not the traffic signals, the four port circulator having ports one to four
20 in the circulating direction coupled one to the outbound fibre from the amplifier/repeater, two to the continuation of the outbound fibre, three to the reflection filter and four to one end of the optical fibre of the coupling means, the three port circulator having its ports one to three in the circulating direction coupled one to the inbound fibre two to the other end of the optical fibre of the coupling means and three

to the continuation of the inbound fibre.

The or each coupling means may comprise an optical fibre two three port circulators and a reflection filter which reflects the test signal wavelength but not the traffic signals, the first three port circulator having its ports one to three in the circulating direction coupled one to the outbound fibre from the amplifier/repeater, two to the continuation of the outbound fibre, and three to one end of the fibre of the coupling means, the second three port circulator having its ports one to three in the circulating direction coupled one to the other end of the fibre of the couplings two to the inbound fibre and three to the continuation of the inbound fibre whilst the reflection filter is connected in the inbound fibre prior to port one of the second three port circulator.

The or at least one of the coupling means may communicate with the inbound fibre to the input side of its associated optical amplifier/repeater.

The or at least one of the coupling means may communicate with the inbound fibre to the output side of its associates optical amplifier/repeater.

The inbound and outbound fibres may extend under water between spaced land masses and the transmission/reception equipment is located on the land masses.

The network may include an optical time domain reflectometer having means for generating the test wavelength different to the traffic signal wavelength on the outbound fibre, for receiving that wavelength from the inbound fibre after reflection and for determining the location of a break as a function of time delay between outgoing and incoming test wavelength signals.

According to another aspect of the invention there is provided a method of fibre break detection in an optical fibre bi-directional transmission system having

amplifiers/repeaters comprising the steps of:-

transmitting on an outbound fibre a test wavelength different from the wavelength of traffic signals, coupling the signal on the outbound line to the inbound line via a filter which permits transfer of the test signal wavelength but not the traffic signal and
5 comparing the time delay between transmitted and returned test signal, and determining the location of a break as a function of the time delay.

In order that the invention and its various other preferred features may be understood more easily, some embodiments thereof will now be described, by way of example only, with reference to the drawings, in which:-

10 Figure 1 is a prior art OTDR network system,

Figure 2 illustrates schematically a modification of part of the system of Figure 1 to provide a network constructed in accordance with the invention,

Figure 3 illustrates schematically an alternative modification of part of the system of Figure 1 to provide a network constructed in accordance with the invention,
15 and

Figure 4 illustrates schematically yet another alternative modification applicable to the systems of Figures 1, 2 or 3 to provide a network constructed in accordance with the invention.

Referring now to Figure 1 there is shown a prior art bidirectional long haul
20 optical transmission system such as is described in reference 1 previously referred to. In this system a transmitter/receiver terminal 10 is coupled to an outbound fibre 12 for transmission signals and an inbound fibre 14 for receiving signals. The terminal 10 has the capability of providing a specific wavelength signal for OTDR purposes on the outbound fibre. The outbound and inbound fibres are routed via optical

amplifiers/repeaters 16, 18, 20, 22, 24, 26 three of which are shown in each line. An optical directional coupler 28 is provided following amplifier/repeater 18 of the outbound line and is arranged to tap a proportion of the optical signal from the line. The coupler is coupled via a fibre 30 to the inbound line at the input to amplifier/repeater 24 via a second directional coupler 32. A break in the outbound line is shown at 34. In use, to detect the break, a test signal is sent from terminal 10 and the outbound fibre 12 is reflected or backscattered by the break coupled via the coupler 28, fibre 30 and coupler 32 to the inbound line back to the terminal 10 where the break location is determined by OTDR.

10 There are however some fundamental limitations imposed by such a coupler arrangement. In order to maintain a low loss path/repeaters for the main traffic signal at the outputs and/or inputs of the amplifiers/repeaters low coupling ratios for the backscattered light must be used which reduces the backscattered signal, and hence the performance of the fiber-break detection system. Furthermore, extra loss may have to be inserted in the backscatter path via an attenuator 36 to reduce the penalty to the inbound return line traffic signal caused by the backscattered outbound line signal. This further limits break detection capability.

 The invention has been arrived at from consideration of the requirements for OTDR in such systems. The method of transferring the backscattered OTDR probe signal from the outbound to the inbound fibre may be viewed in two parts: Extracting the backscattered signal from the outbound fibre, and adding it to the inbound fiber. Furthermore this should be done with minimal effect on the magnitude of the traffic signals.

 The invention and its various other preferred features will now be described

by reference to the further diagrams which illustrate modifications of the arrangement illustrated in Figure 1 with only the modified portion being illustrated. The same reference numerals are employed to identify the same parts of Figure 1.

In Figure 2, instead of employing an optical coupler at the output of the amplifier there is provided an optical circulator 38 and a reflection filter 40 which is designed to reflect the OTDR wavelength. As will be seen the output of the amplifier is connected to a first port of the circulator, the second port of the circulator is coupled to the output line and on to the amplifier 20, the third port is coupled to the reflection filter 40 and the fourth port is coupled to the cross connection fibre 38. In use, a traffic and/or test signal sent along the outbound fibre 12 enters the circulator 38 at the first port and passes out through the second port for onward routing to the amplifier 20. As a result of a break at 34 backscattered light which comprises traffic and/or test signals is routed back to the second port of the circulator 38 out through the third port to the reflection filter 40 where the traffic signal is absorbed and the test signal reflected back to the third port of the circulator and out from the fourth port onto the fibre 30 for cross coupling to the inbound line at the input to the amplifier/repeater 24. The line traffic signal and OTDR probe signals are required to be of different wavelengths, so that the filter reflects only the required OTDR test wavelength. The filter may be of any suitable reflection type e.g. a fiber Bragg Grating.

Figure 3 illustrates an alternative arrangement employing a transmission filter 42 designed to pass the OTDR test signal wavelength but not the traffic wavelength. In this arrangement a three port optical circulator 44 is employed. The output of the amplifier 18 is coupled to the first port of the optical circulator, the second port is coupled to the output line and on to the amplifier 20 and the third port is coupled via

the cross connection fibre 30 to the filter 42. In use a traffic and/or test signal is sent along the outbound fibre 20 enters the circulator 44 at the first port and passes out through the second port for onward routing to the amplifier 20. As a result of a break at 34 backscattered light which comprises traffic and/or test signals is routed back to the second port of the circulator and out through the third port onto the fibre 30 to the filter 42 which permits passage of the test signal wavelength but which prevents passage of the traffic signal wavelength which is then coupled to the inbound line at the input to the amplifier/repeater 24.

In the arrangement of Figure 3, instead of employing a three port circulator an optical coupler such as shown as 28 in Figure 1, may be employed although this is less advantageous because the coupling factor employed is a trade off between permitting transfer of the returning test signal whilst permitting adequate transmission of the traffic signal.

The coupling of the returning backscattered signal on the line 30 after filtering can be effected by a simple optical coupler 32 in the manner illustrated in Figure 1. However, even if this is a relatively high ratio tap coupler there will be attenuation of the test signal. A preferred arrangement is to employ a three port circulator such as 46 shown in Figure 4. Here the line 30 is coupled to the first port of the circulator, the return line from the amplifier 22 is coupled via a reflection filter to the second port, which reflection filter is arranged to pass the signal wavelength but reflect the test wavelength, and the third port is coupled to the input of the amplifier 24. In use, a backscattered test signal arriving on the line 30 enters the first port of the circulator, exits the second port but is reflected back to the circulator by the filter 48, exits the third port for onward transmission back to the transmit/receiver terminal 16 via the

amplifier 24. A traffic signal arriving on the inbound fibre from the amplifier 22 passes through the reflection filter 48 into the second port of the circulator 46, out through the third port and onward to the transmit/receive terminal 16 via the amplifier/repeater 24.

5 With the arrangement of Figure 4 employed with the arrangement of Figure 3 the transmission filter 42 may be dispensed with as the reflection filter 48 will not permit reflection of the backscattered traffic signal. The loss of the backscatter path is reduced by the use of a circulator rather than a high ratio tap coupler. This considerably increases the span length that can be measured by the OTDR system.

10 The line transmission penalty on the inbound fiber is minimised by the use of a filter to ensure that only the narrow band around the OTDR probe wavelength is coupled back to the return fiber. The circulator acts as an output isolator for the amplifier, which is required anyway, so the number of extra components required to implement the OTDR function is minimised.

15 Whilst any suitable reflection filter can be used for the components 40, 48 a Bragg Grating is particularly suitable. Any suitable transmission filter can be employed for the filter 42 for example a multi layer dielectric filter or a Fabre Perot filter.

20 Although the embodiments illustrated and described employ cross coupling between the output of an amplifier/repeater in one path and the input of an amplifier/repeater in the other path, which is the preferred arrangement, the coupling may be effected between the output of the amplifier/repeater in one path and the output of an amplifier/repeater in the other path.

For ease of description coupling of a signal from the outgoing fibre to the

incoming path is described. It will be appreciated that similar coupling arrangements can be provided between the incoming fibre and the outgoing fibre for OTDR interrogation from the terminal at the opposite end of the system. Such a coupling is schematically illustrated in Figure 1 between the output of the amplifier 24 and the
5 input 18 and similar couplings to those described in connection with Figures 2 to 4 can be employed without departing from the scope of the present invention.

Whilst for simplicity of description cross coupling just between the amplifier/repeaters 18 and 24 are illustrated and described. However, it will be appreciated that similar cross couplings can be provided between other
10 amplifiers/repeaters or all of the amplifiers/repeaters such as 16, 26 & 20, 22 can be employed. Such arrangements are considered to fall within the scope of this invention.

CLAIMS:

1. A bi-directional optical signal transmission network, comprising an outbound (12) and an inbound (14) fibre each including an optical amplifier/repeater (18/24), optical coupling means (30,38,40) communicating between one of the fibres (12), to the output side of the amplifier/repeater (18), and the other fibre (14) and including a filter (40) which is arranged to permit transfer of a test signal wavelength between the outbound and the inbound fibre but which prevents transfer of a unwanted traffic signal.
2. A network as claimed in claim 1, comprising an additional optical coupling means communicating between said other fibre (14), to the output side of the amplifier/repeater (24), and said one of the fibres (12) and including a second filter which is arranged to permit transfer of a test signal wavelength between the inbound and outbound fibre but which prevents transfer of a unwanted traffic signal.
3. A network as claimed in claim 1 or 2, wherein the or each coupling means comprises an optical fibre (30) including a transmission filter (42) which permits passage of the test signal wavelength but which prevents transfer of the unwanted traffic signal, which coupling means is provided at each end with a tap coupler (28,32) to a different one of the inbound and outbound fibres.
4. A network as claimed in claim 1 or 2, wherein the or each coupling means comprises an optical fibre (30) including a transmission filter (42) which permits passage of the test signal wavelength but which prevents transfer of the unwanted

traffic signal, which coupling means comprises one end with a 3 port circulator (44) having input and output ports for the outbound fibre (12) and an intermediate port coupled with the fibre (30) of the coupling means and at the other end a tap coupler (32) to the inbound fibre (14).

5 5. A network as claimed in claim 1 or 2, wherein the or each coupling means comprises an optical fibre (30) including a transmission filter (42) which permits passage of the test signal wavelength but which prevents transfer of the unwanted traffic signal, which coupling means comprises at each end a 3 port circulator (44,46) one for each of the outbound (12) and inbound (14) fibres each circulator having an
10 input and output port for their particular outbound or inbound fibre and another port coupled with the fibre (30) of the coupling means.

6. A network as claimed in claim 1 or 2, wherein the or each coupling means comprises an optical fibre (30), a four port circulator (38), a tap coupler (32) and a
15 reflection filter (40) which reflects the test signal wavelength but not traffic wavelengths, the four port circulator having its ports one to four in the circulating direction coupled one to the outbound fibre (12) from the amplifier/repeater (18), two to the continuation of the outbound fibre three to the reflection filter (40) and four to one end of the optical fibre (30) of the coupling means whilst the tap coupler is coupled
20 via the other end of the optical fibre (30) of the coupling means to the inbound fibre (12).

7. A network as claimed in claim 1 or 2, wherein the or each coupling means

comprises an optical fibre (30), a four port circulator (38), a three port circulator (46) and a reflection filter (48) which reflects the test signal wavelength but not the traffic signals, the four port circulator having ports one to four in the circulating direction coupled one to the outbound fibre (12) from the amplifier/repeater (18), two to the continuation of the outbound fibre, three to the reflection filter (40) and four to one end of the optical fibre (30) of the coupling means, the three port circulator (46) having its ports one to three in the circulating direction coupled one to the inbound fibre (14) two to the other end of the optical fibre (30) of the coupling means and three to the continuation of the inbound fibre.

10 8. A network as claimed in claim 1 or 2, wherein the or each coupling means comprises an optical fibre (30) two three port circulators (44,46) and a reflection filter (48) which reflects the test signal wavelength but not the traffic signals, the first three port circulator (44) having its ports one to three in the circulating direction coupled one to the outbound fibre (12) from the amplifier/repeater (18), two to the continuation of the outbound fibre, and three to one end of the fibre (30) of the coupling means, the
15 second three port circulator (46) having its ports one to three in the circulating direction coupled one to the other end of the fibre (30) of the couplings two to the inbound fibre (14) and three to the continuation of the inbound fibre whilst the reflection filter (48) is connected in the inbound fibre prior to port one of the second
20 three port circulator (46).

9. A network as claimed in any one of the preceding claims, wherein the or at least one of the coupling means communicates with the inbound fibre (14) to the

input side of its associated optical amplifier/repeater (24).

10. A network as claimed in any one of claims 1 to 8, wherein the or at least one of the coupling means communicates with the inbound fibre (14) to the output side of its associated optical amplifier/repeater (24).

5 11. A network as claimed in any one of the preceding claims, wherein the inbound (14) and outbound (12) fibres extend under water between spaced land masses and the transmission/reception equipment is located on the land masses.

10 12. A network as claimed in any one of the preceding claims, including an optical time domain reflectometer (10) having means for generating the test wavelength different to the traffic signal wavelength on the outbound fibre (12), for receiving that test wavelength from the inbound fibre (14) after reflection and for determining the location of a break (34) as a function of time delay between outgoing and incoming test wavelength signals.

15 13. A method of fibre break detection in an optical fibre bi-directional transmission system having amplifiers/repeaters comprising the steps of:-
transmitting on an outbound fibre a test wavelength different from the wavelength of traffic signals, coupling the signal on the outbound line to the inbound line via a filter which permits transfer of the test signal wavelength but not the traffic signal and comparing the time delay between transmitted and returned test wavelength signals, and
20 determining the location of a break as a function of the time delay.

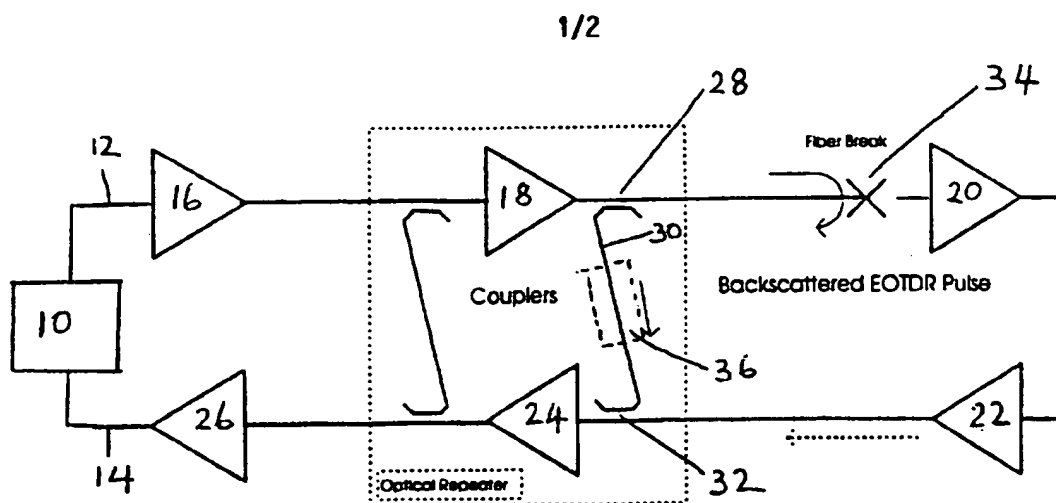


Fig 1 - PRIOR ART

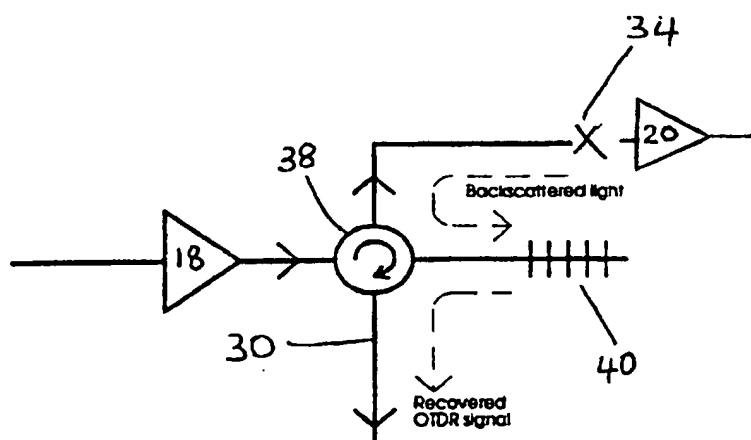


Fig 2

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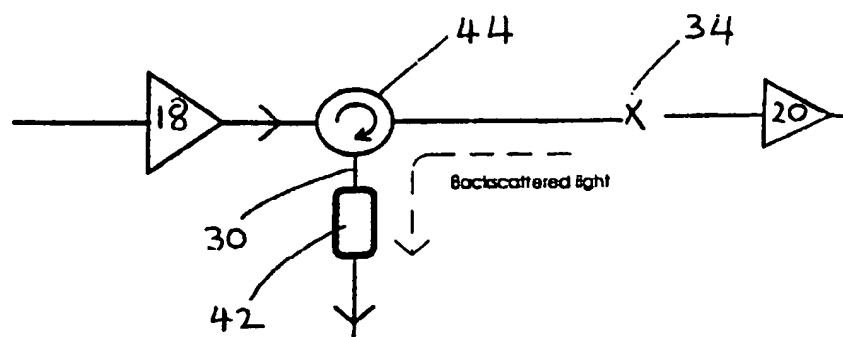


Fig 3

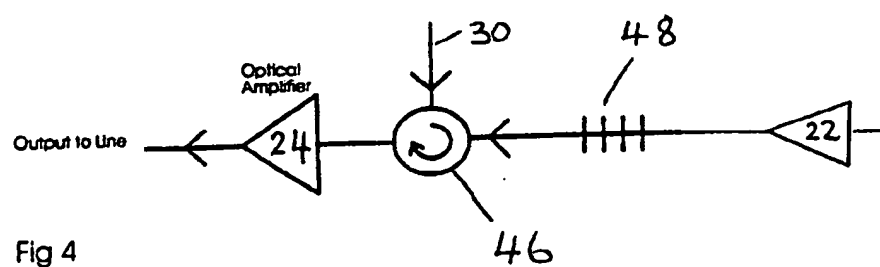


Fig 4

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 96/03145

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H04B10/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 111 582 A (ANT NACHRICHTENTECHNIK) 27 June 1984 see page 1, line 8 - line 12 see page 2, line 34 - page 3, line 23 see page 4, line 16 - page 5, line 22 see figures 1-3	1,3
Y	---	2,9-13
Y	GB 2 267 792 A (KOKUSAI DENSHIN DENWA) 15 December 1993 see abstract see page 3, line 5 - line 24 see page 14, line 1 - page 15, line 12 see page 19, line 5 - line 16 see figures 1,3 ---	2,9-13
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
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Authorized officer

Williams, M.I.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/03145

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	IEEE PHOTONICS TECHNOLOGY LETTERS, vol. 3, no. 11, November 1991, NEW YORK US, pages 1001-1003, XP000232698 SATO ET AL: "OTDR in optical transmission systems using Er-doped fiber amplifiers containing optical circulators" see page 1001, left-hand column, paragraph 2 - right-hand column, paragraph 1 see figures 1,2 ---	4-8
A	EP 0 390 320 A (GEC PLESSEY) 3 October 1990 see column 2, line 42 - column 3, line 38 see figures 1,2 -----	1-13

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